PNI SENSOR CORPORATION

PNI White Paper

Accurate Compassing in Harsh Environments

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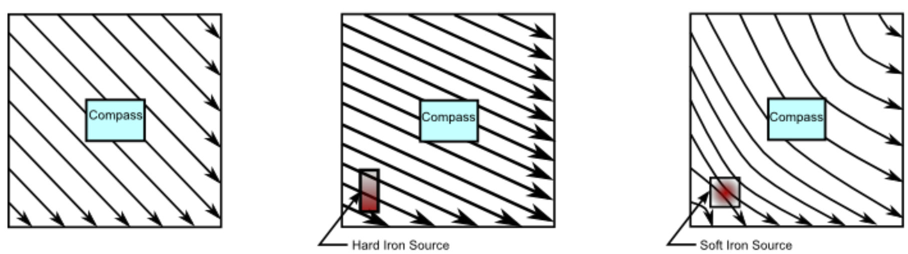
Today's electronic compasses are built to withstand harsh environments – mechanical shocks, extreme temperatures, and battlefield conditions. Yet the most challenging environment for electronic compasses is transitory magnetic field distortion encountered in everyday situations.

Materials that distort Earth's magnetic field surround us. Ferrous materials such as rebar in floors and beams in walls, batteries, automotive parts, magnets in speakers, electric motors, cell phones, and DC currents in wires can create either permanent or transitory distortions to the local magnetic field. Yet, with recent software advancements, these distortions can be compensated for in modern electronic compasses.

Correcting for Permanent Local Field Distortions

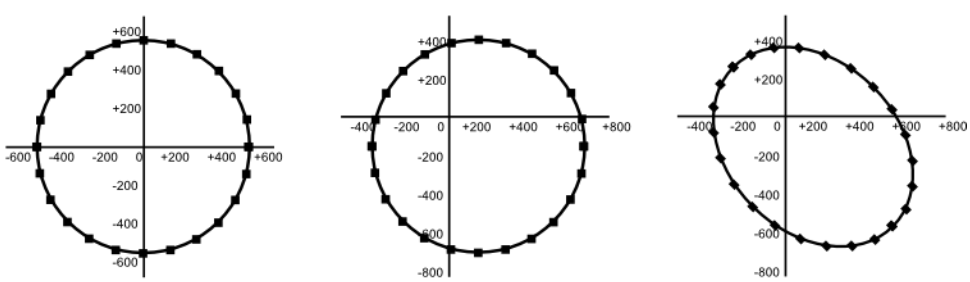
Permanent distortions are caused by magnetic distortion sources placed near the electronic compass within a user's system. Such items can include mounting brackets, batteries, screws, nearby electronic components, etc.. These can distort the magnetic field either by adding a magnetic field vector to Earth's field (hard iron distortion) and/or by distorting the local field (soft iron distortion).



Undistorted Field | Hard Iron Distortion | Soft Iron Distortion

Figure 1

A standard 2-axis compass measures the magnetic field strength in one horizontal direction (x axis) and in the horizontal direction orthogonal to the x axis (y axis). When rotated through 360°, the compass maps a circle of points as shown in the "Undistorted Field" diagram in Figure 2a. When a hard iron distortion is introduced which rotates with the compass, the center of the circle is offset (Figure 2b). Introducing an additional soft iron distortion results in an ellipse (Figure 2c).



a) Undistorted Field | b) Field with Hard Iron Distortion | c) Field with Hard & Soft Iron Distortion

Figure 2

To maintain accurate heading information, one must transform the offset ellipse of the "Field with Hard & Soft Iron Distortion" back to the centered circle of the "Undistorted Field". This is done with a calibration routine performed while the compass is fixed relative to the host system. And getting this right is non-trivial. At PNI, we have been refining our calibration algorithms for 20 years, such that we can now reduce calibrated heading error to <0.3° in real world conditions with our TCM electronic compass.

Correcting for Transient Local Field Distortions

A more challenging scenario is when the local magnetic field temporarily changes, such as when a vehicle passes close by or the compass momentarily passes close to a magnetic distortion. In this case, the source of distortion is not a permanent part of the user's system, so recalibration is usually infeasible.

To address this challenge, a gyroscope can be integrated into the compass to recognize when motion occurs. Generally speaking, if the gyroscope indicates no motion is occurring, but the magnetic sensors show the heading is changing, this is recognized as a transient magnetic distortion. Sophisticated software algorithms, which are available in some gyro-stabilized compasses and attitude and heading reference systems (AHRS), can correct for these situations, thus providing continuous, reliable heading data.

PNI has recently developed the FieldForce Trax, an AHRS module which provides an accurate heading even when encountering magnetic distortion and experiencing erratic motion. It employs a refined Kalman filtering algorithm that intelligently fuses PNI's patented Reference Magnetic Sensors output with gyroscope and accelerometer outputs to overcome errors due to motion and changes in the local magnetic field. Figure 3 provides heading information for a standard electronic compass and for the Trax AHRS as each travels in a straight line (constant heading) and is twice brought close to a source of magnetic distortion.

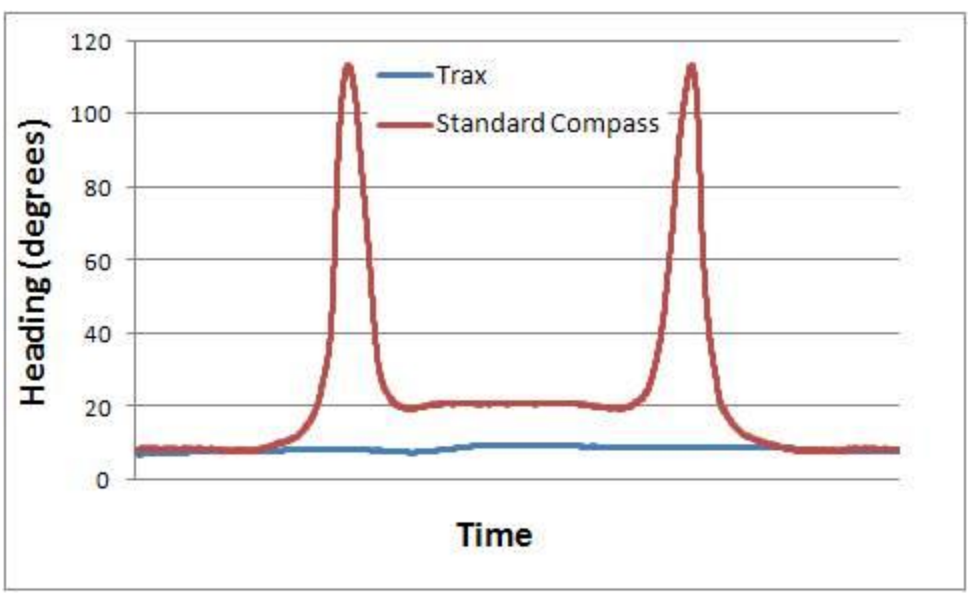


Figure 3

While magnetic compasses have existed for thousands of years, only recently has software been able to compensate for some of the limitations of magnetic compasses. Indeed, the development of calibration algorithms and magnetic transient compensation algorithms has largely overcome what were considered the harsh environment conditions for compassing. Having said this, the effectiveness of electronic compasses today is highly dependent on how these algorithms are implemented.